Influent load prediction
using low order adaptive modeling

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Introduction

- Future influent flow in a tunnel system is predicted using one model for dry weather and one for stormwater runoff.
- Dry weather flow is formed as an average of previous dry weather days using a filter.
- An adaptive stormwater model with input from a weather radar is used to make predictions of future runoff flow.
- The flow predictions help maximize use of the buffer capacity in the tunnel system and thereby reducing variations in pumping rate.

The Rya WWTP treats wastewater from the Göteborg region with 750 000 pe connected in an area of approximately 200 km². Dry weather load is 210 000 m³/d and peaks are up to 1 425 000 m³/d.

Methods

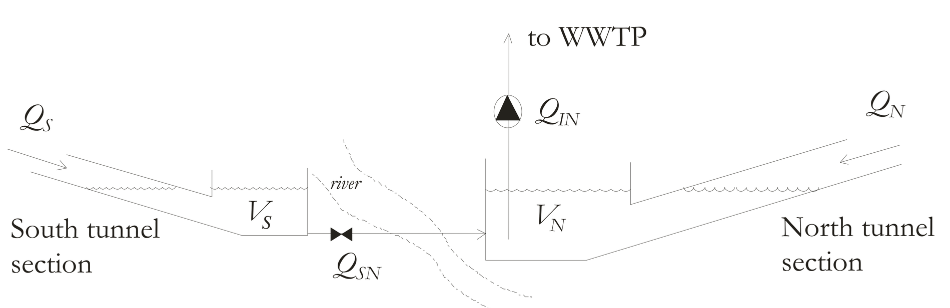
Flow model

- A model is used to calculate the momentaneous flows to the two tunnel sections that gives the most flow attenuation in the tunnel system.
- Measured flows are Q_{SN}, connecting the south tunnel section through an inverted siphon under the Göta River, and Q_{IN}, influent pumping rate to the Rya WWTP.
- With Q_N and Q_S being the flow in the north and south tunnel sections respectively, the flow model can be written as

$$Q_N = \frac{dV_N}{dt} + Q_{IN} - Q_{SN}$$

$$Q_S = \frac{dV_S}{dt} + Q_{SN}$$

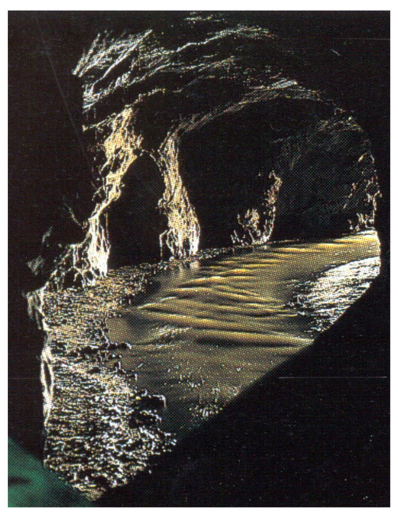
- The rate of volume change (dV/dt) can not be directly measured and therefore has to be estimated from the rate of level change (dh/dt).
- The calculated influent flows is then used to identify the flow prediction models.



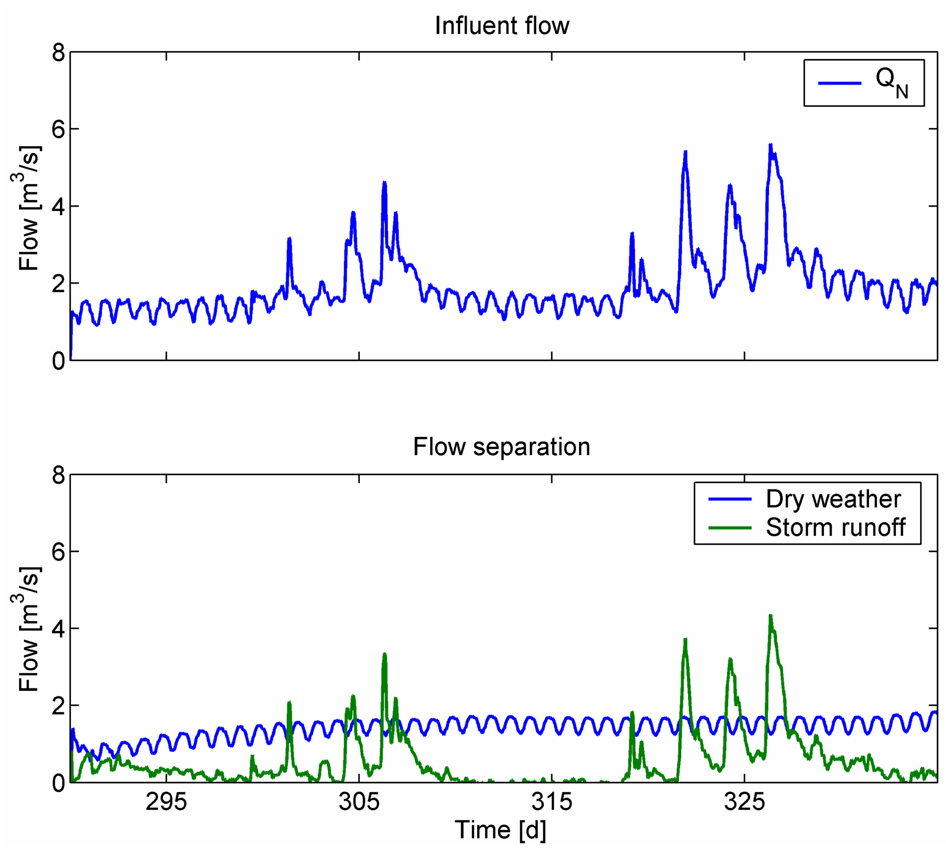
Wastewater is transported to the Rya WWTP through a large tunnel system comprised of two main branches of about the same size separated by the Göta River. Total storage capacity in the tunnel system is approximately 250 000 m³.

Flow prediction

- The dry weather flow model is used to describe the base load from households and industries.
- The dry weather model consists of a flow pattern added to a bias value. The flow pattern is updated every hour to adapt itself to changes in flow appearance.



- A filter is used to update the bias value and flow pattern. By setting a filter parameter the weight can be determined for old and new values respectively. Using this model the influent flow can be separated into dry weather and stormwater runoff flow.



The dry weather flow model is adapting to the influent flow using a filter. By subtracting the dry weather load from the total flow the stormwater runoff flow is received.

- A parametric model is used to describe the relationship between rainfall and runoff flow. It is a so called ARX model (AutoRegressive with eXogenous input) with recursive updating of the model parameters.
- The model states how the future flow $y(t+1)$ depends on previous flow and rain u according to

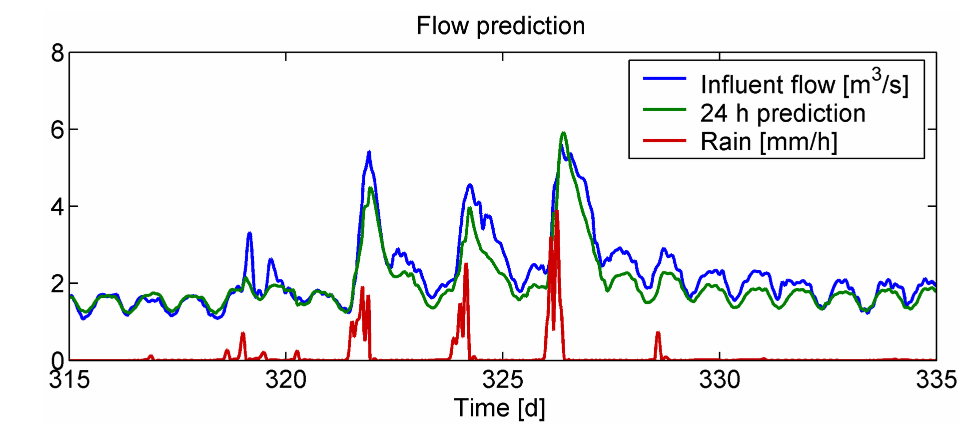
$$y(t+1) = -a_1 y(t) - a_2 y(t-1) + b_1 u(t)$$

where $y(t)$ denotes current flow, $y(t-1)$ is the flow in the previous sample and $u(t)$ is current rain.

- The model parameters a_1, a_2 and b_1 determines how much weight should be put on past y and u values to estimate the future y.
- The values of the model parameters are continuously adapted to match the real system using a recursive least square (RLS) algorithm.
- The adaptation rate is determined by a "forgetting factor" used in the algorithm.

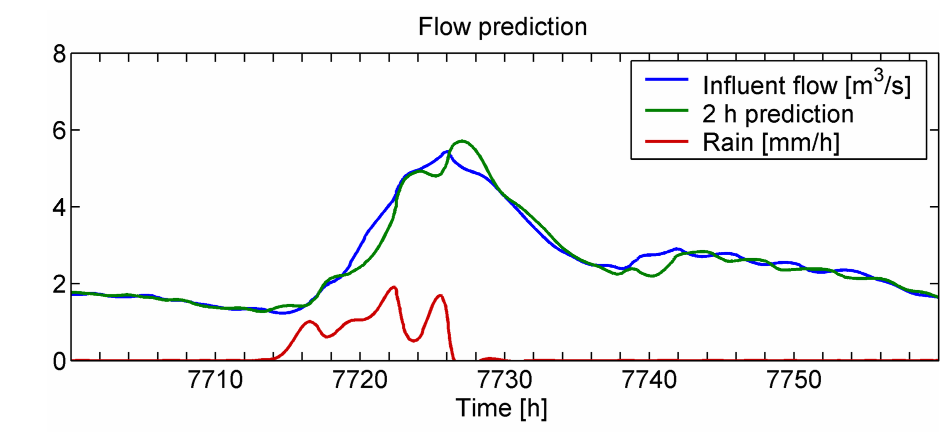
Results and discussion

- The results show that it is possible to make good flow predictions for periods up to 24 hours during dry weather.
- With a reliable rain prognosis it is also possible to make a 24 hour estimation of future stormwater runoff flow.



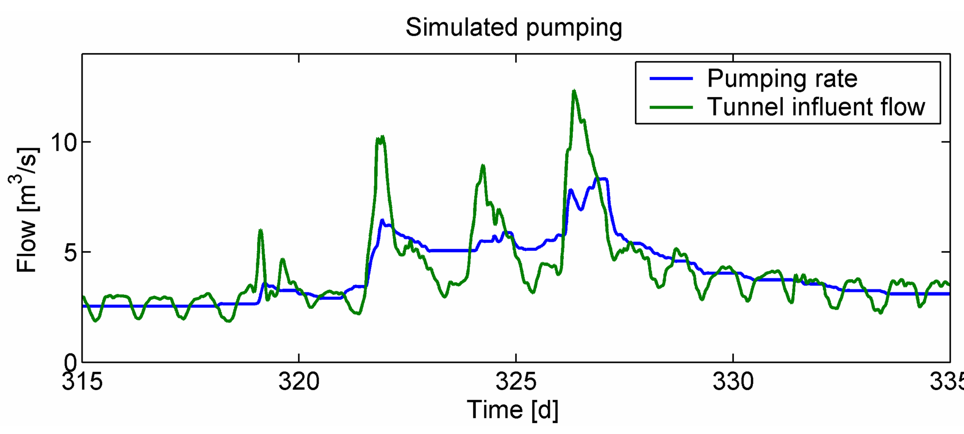
The dry weather and stormwater runoff models are combined to make a prediction of the total influent load. The future runoff component is estimated using a 24 hour rain prognosis.

- The reliability of the prediction can be increased by shortening the time horizon.



During storms the shorter predictions are much more accurate as seen in this 2 hour prediction.

- Using flow predictions it is possible to automate the inlet pump control system to react prior to changes in tunnel influent flow.



With the help of flow predictions, the inlet pump control system can use the buffer capacity in the tunnel system and start pumping before a flow increase and thus evening out the flow to the WWTP, as seen in this simulation.

Conclusions

- Future dry weather flow can be estimated as an average of previous flow.
- Stormwater runoff flow can be roughly estimated up to 24 hours ahead if a rain prognosis is used as an extra input to the model. Reliability is increased with shortened prediction time.
- The adaptive model eliminates the need for historical data and provides better results than a static model for a system that varies over time.
- Flow predictions with input from weather radar has been implemented in the Rya WWTP's SCADA system.